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A method based on image segmentation for the analysis of the orientation of rod-like objects / Sparavigna, Amelia Carolina. - ELETTRONICO. - (2019). [10.5281/zenodo.2567394]

Availability:

This version is available at: 11583/2729621 since: 2019-03-28T11:27:31Z

Publisher:

Zenodo

Published

DOI:10.5281/zenodo.2567394

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A method based on image segmentation for the analysis of the orientation of rod-like objects

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Here we show a method of image processing, which can be applied to the measurement of the orientation of rod-like objects. The method is based on an image segmentation recently developed and used for the analysis of micrographs. The segmentation allows to determine specific objects in the image, the orientation of which can be measured with respect to the axes of the image frame. The orientation is determined by means of the elements of a matrix of inertia. Two lengths are associated to the elements of the diagonal of the matrix. Their ratio is giving the arctangent of an angle, between 0 and 90 degrees; the element outside the diagonal is giving the sign of this angle, which is measuring the orientation of segmented rod-like objects.

Keywords: Image Processing, Image Segmentation, Orientation of segments.

Written 17 February 2019. DOI: 10.5281/zenodo.2567394

In image processing, a segmentation is a process of partitioning an image into multiple sets of pixels, that are defined as "super-pixels", "segments", or "objects", in order to have a representation which is simpler than the original one and, as a consequence, more useful for any desired analysis [1]. For this reason, the segmentation of images is often used in many applications requiring the processing of single images or for the stacking of maps in order to have 3D reconstructions [2-4].

The typical use of the image segmentation is that of locate objects into the image frame, their edges and the boundaries among them. Specifically, the segmentation is a process of assigning a label to every pixel in an image, such that the pixels having the same label share certain characteristics [4]. As a consequence, the result of the segmentation is a set of "segments" that are covering some parts or the whole image. The set of their contours, that is of their "edges", is usually known as "edge detection".

Several methods exist for segmentation, as we can appreciate from [4,5].

Recently, we have proposed the approach discussed in detail in [6-8]. The method had been applied to several cases: the study of the pores resulting from freeze-drying of pharmaceutical solutions [8,9], the size of the fly ashes [10], of natural and artificial alveolar structures [11,12], the measurements of the size of tubules in phloem and xylem of plants [13], analysis of fabric textures [14] and microstructures in ductile cast iron [15]. In [16] we have implemented the measurements of the shape of the blood cells, and in [17] of the contours of some domains, with an approach suitable for the estimation of Hausdorff-Besicovitch dimensions [18].

The segmentation used in the given references is based on a thresholding of the original image, to have in it black objects in a white background. Each object in the image was labelled by means of an index, and coloured, so that each object was characterized by a specific colour. As shown in the cases discussed in [16] and [17], it is possible to provide, besides the area of each object, also the length of its boundary. Actually a rose of 16 distances from the "centre of mass" to object's edges can be given [16].

Here we want to show how we can measure the direction of a segmented object.

First, let us define the coordinates x_{cm} and y_{cm} in the image frame of the "centre of mass" of the object. Coordinates are defined as follow:

$$x_{cm} = \sum_i x_i / N, \quad y_{cm} = \sum_i y_i / N \quad (1)$$

In (1), index i is running on the pixels of the object and N is the total number

of pixels of the object. x_i and y_i are the coordinates of the i -th pixel. The method to determine the direction of the domains is based on the elements of the "matrix of inertia", a quantity used in physics and mechanics to describe the motion of rigid bodies. For each object in the image frame, we define the elements of the matrix as:

$$I_{xx} = \sum_i (y_i - y_{cm})^2, \quad I_{yy} = \sum_i (x_i - x_{cm})^2, \quad I_{xy} = I_{yx} = - \sum_i (x_i - x_{cm})(y_i - y_{cm}) \quad (2)$$

Let us define two lengths associated to the elements of the diagonal.

$$L_{xx} = \sqrt{(I_{xx})/N}, \quad L_{yy} = \sqrt{(I_{yy})/N} \quad (3)$$

From them, we can obtain an angle as:

$$\theta = \arctan(L_{yy}/L_{xx}) \quad (4)$$

That is, the ratio of the two lengths (3), associated to the elements of the diagonal, is giving the arctangent of an angle, between 0 and 90 degrees. The element outside the diagonal is giving the sign of the angle, in the following manner:

$$\theta = \frac{I_{xy}}{|I_{xy}|} \arctan(L_{yy}/L_{xx}) \quad (5)$$

Equation (5) is defining the direction of the domain. Angles are counted from the horizontal x-axis.

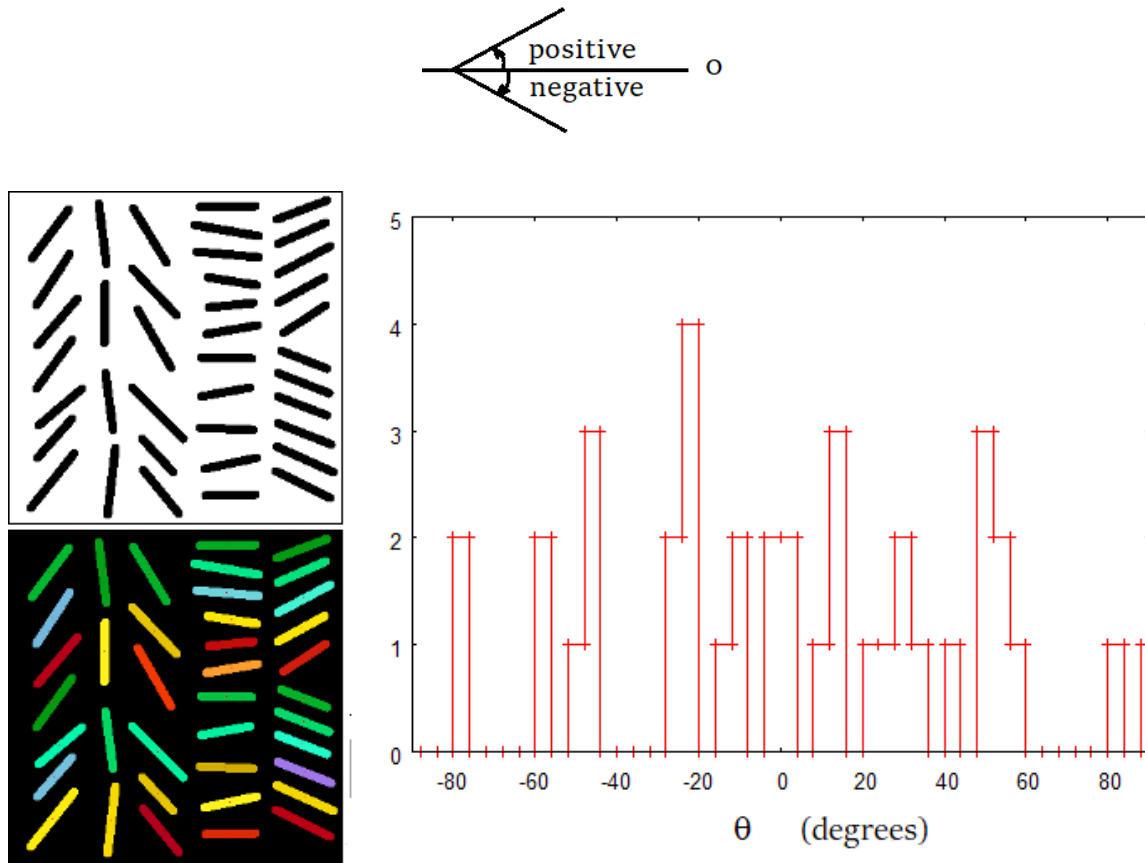


Figure 1: Rod-like objects, their labelling by colours and related angles.

In the Figure 1 we consider a simple application of the method. Let us imagine

to have an assembly of rod-like segments. In the same figure, we can see the segmentation, where each rod is labelled by a different colour. For each coloured domain, angle (θ) is calculated. The distribution of the angles is given in the diagram. The range from -90° to $+90^\circ$ is subdivided in intervals, equally spaced. N is the number of rods having an angle in the corresponding interval.

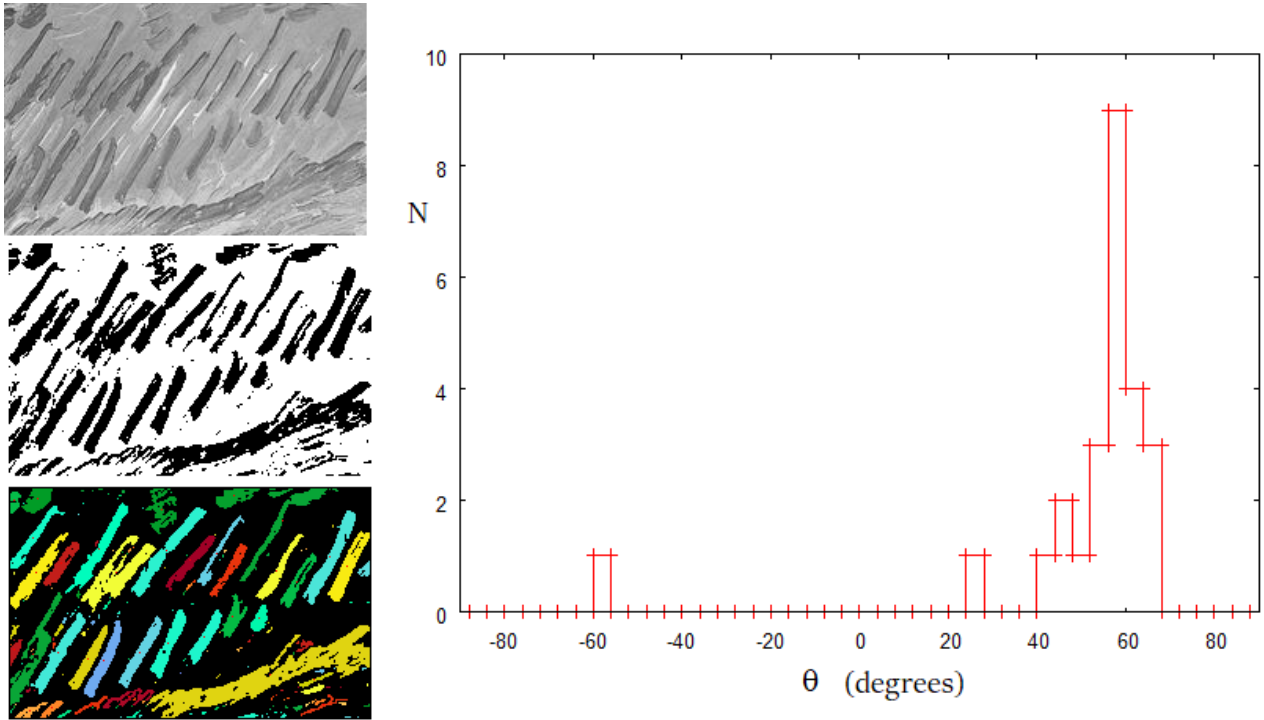


Figure 2: Brushstrokes, their labelling by colours and related angles.

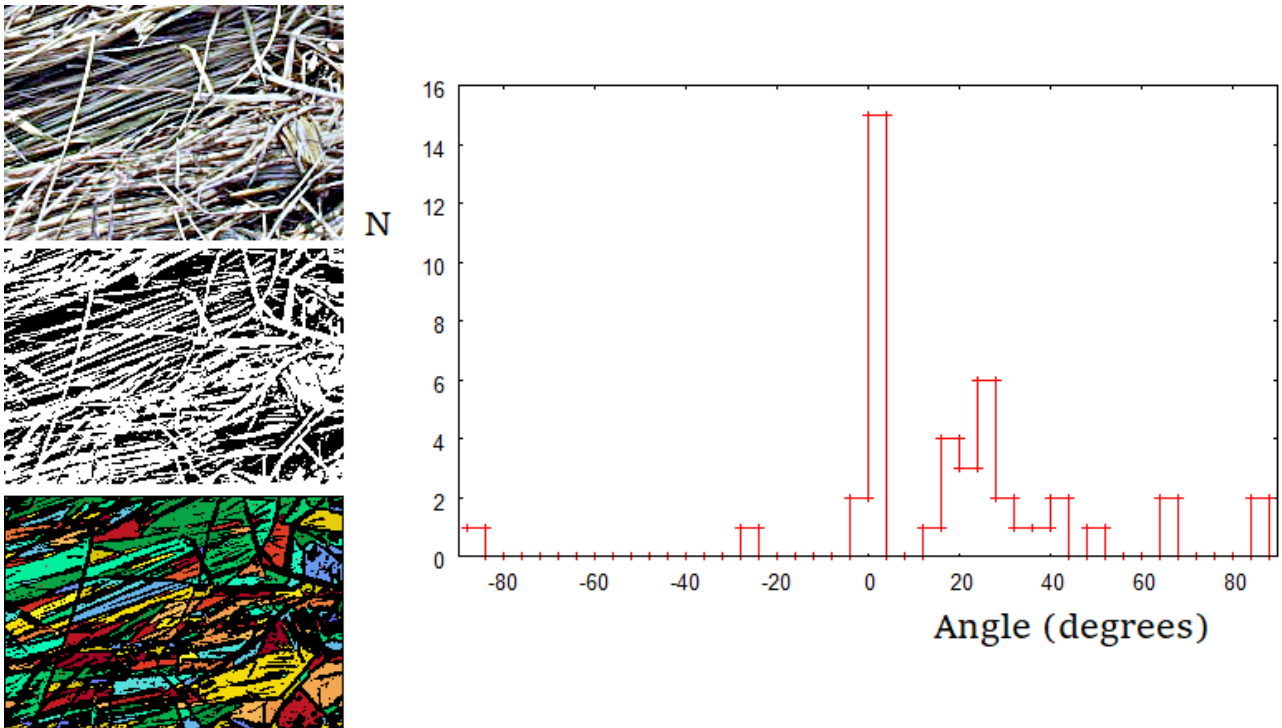


Figure 3: Straw. A detail from a picture by Green for Wikipedia.

The proposed method can be applied to the study of images where objects have a

rod-like shape. For instance, we can use it to measure the angles of brushstrokes in painting. In the Figure 2, it is shown an example, where the method is applied to the brushstrokes in a detail of "Wheatfield with Crows", 1890, by Vincent Van Gogh, Van Gogh Museum, Amsterdam. In the case of the Figure 2, we have considered objects having a size, that is an area, above a given value A_L . Sometimes, for certain images, such as that given in the Figure 3, it is better to use also an upper value for the area of the objects, A_H . Therefore, in the Figure 3, angles are measured only for those objects having an area A between A_L and A_H , that is, $A_L < A < A_H$. In this manner we can avoid to count objects which are smaller or larger than a desired size.

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